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# Measuring the Effectiveness of Nonpoint Source Control Techniques for Aquatic Protection

## A Summary Report

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Documenting the effectiveness of nonpoint source (NPS) pollution control technologies requires a technique- and a site-specific monitoring program.This report details an evaluation method developed to determine which NPS control technique should be used, and how to evaluate the control's effectiveness.

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# EXECUTIVE SUMMARY

Attention to nonpoint source pollution (NPSP) originating from stormwater runoff is growing as point sources are eliminated or controlled. NPSP has largely escaped regulation because of frequent difficulty in identifying a culpable source and quantifying its environmental impact, as well as from little knowledge of effective control techniques. The lack of corporate knowledge of NPSP control techniques results from limited historical regulation and from poorly developed methods to measure the techniques' effectiveness. The refinement of a single or small set of control techniques will not be appropriate for all NPSP due to the diversity of pollutants in runoff. Several measures of effectiveness may be needed for each technique due to site-specific variations.

The Navy will benefit from testing NPS control techniques now. Future regulation of NPSP will leave little flexibility for methods of regulation of remediation and monitoring. The interim provides an opportunity to develop and document effective and low cost solutions which may be particularly suited to Navy needs.

This report develops the principles appropriate to measuring effectiveness of NPSP control techniques.

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# PURPOSE

This report outlines the principles appropriate to measuring nonpoint source pollution (NPSP) for validating the effectiveness of an NPSP control technique. Categories of control and validation methods are used in this report.

# BACKGROUND

## NONPOINT SOURCE DEFINITION

NPSP includes all species of pollution (metals, organics, etc.) in every medium (air, water, soil) that come from diverse sources. No clear distinction exists between point and nonpoint sources (NPS). Nonpoint sources can become point sources and vice versa. As an illustration, polluted runoff from paved areas or agricultural fields is "nonpoint." If the runoff in this dispersed form flows into nearby streams and/or groundwater, it remains "nonpoint." If it is collected and discharged via an outfall, it may be classified as a "point" source. This report uses the term "nonpoint" in a broad context: contaminated rainwater runoff, groundwater, dispersed air, and soil pollution are all NPSP.

## WHY NPSP IS A PROBLEM

The impact of NPSP has historically been neglected due to regulatory emphasis on monitoring and remediating point sources. As point sources were eliminated or controlled, the relative importance of NPSs grew. Based on responses from 47 states, the Environmental Protection Agency (EPA, 1984) found that 24 states reported NPSP was a major source of water degradation, 21 states reported that NPSP was a problem of an undetermined magnitude, and 2 states classified NPSP as a potential pollution problem.

A number of inherent features of NPSP make assessment and management difficult (EPA, 1984):

1. Pollutants generated by nonpoint sources are often highly complex and difficult to track.

2. A certain amount of nonpoint source runoff is of natural origin.

3. Separating the impacts of point and nonpoint sources is often difficult.

4. Baseline water quality information is lacking, because, historically, monitoring programs have been oriented toward point sources of pollution.

5. Cause-and-effect relationships between nonpoint sources and particular water quality problems are hard to establish because of the diffuse nature of nonpoint runoff, and the many land use activities within a given watershed.

6. The performance of appropriate management controls is highly dependent on site-specific factors and is, therefore, difficult to predict and assess.

"NPS pollution is caused by diffuse sources that are not regulated as point sources and normally is associated with agriculture, silviculture [forestry] and urban run-off, run-off from construction activities, etc...generally results from land run-off, precipitation, atmospheric deposition, or percolation" (EPA, 1987). The EPA's 1987 definition highlights the two main difficulties with remediation: (1) NPSP has diverse origins and, thus, numerous constituents, and (2) broad spatial distribution means the remediation must be implemented over a broad physical area.

## PREDICTING NPSP EFFECTS

The difficulty in measurement of NPSP has prompted prediction techniques based on more easily measured parameters and modeling. Gannon (1988) describes an advisory sign which is posted at a recreational water area following rain storms that warn of fecal coliform contamination. This contamination resulted from a quantified relationship between fecal loading and precipitation rate. Modeling (for example; Couillard, 1988; Gaboury et al., 1987) predicts NPSP and helps predict the impact on NPSP loading resulting from using control techniques.

## FOCUSING ON WATER

Since runoff is the predominant form of NPSP in aquatic and coastal marine areas, this report addresses the bulk of the runoff problem. Water quality, however, is linked to air and soil pollution. Rainfall scavenges pollutants from the air and, in turn, becomes contaminated. Runoff from contaminated soil carries particulate and dissolved contaminates. These other forms will be mentioned to remind the reader of the broad scope of the problem.

# CONTROL TECHNIQUES

## BMPs AND STRUCTURAL CONTROLS

NPS control techniques are designed to reduce or eliminate pollution discharge. The diverse character of NPSP requires a diverse approach to control techniques. Methods to monitor the effectiveness of these techniques must also be varied.

Pollution reduction can occur via two main mechanisms: (1) best management practices (BMPs) that modify the process or activity that generates the pollution (i.e., reducing the use, production, or discharge), and (2) structural approaches that entail treatment of the pollution before discharge.

The most ideal NPS control technology modification of a process that uses (or produces) hazardous material allows a less or nonhazardous process to be used. Environmental preservation and worker safety are achieved. It must be emphasized that this approach should be the first one analyzed for remediation of an NPSP problem. Management changes can also be effective: Moving polluting activities to a location with less likelihood of a contaminating runoff is an example.

If reduction in the production of the pollution is not achievable, then "end-of-the-line" structural controls must be applied. Structural controls are discussed in the following paragraphs. The category into which a technique is classified has a marked effect on the approach to effective monitoring.

## DISPERSAL vs. COLLECTION

NPSP may be dispersed at the site of origin to allow small scale technologies and natural processes to effect remediation. Roadways without curbs are an example. Runoff goes into the soil adjacent to the roadway for biological degradation.

NPSP may be collected into one or a few discharge points. Roadways with curbs to channel runoff to storm drains are an example of how larger scale technologies (such as those of public waste water treatment plants) may be applied.

## CONTAINMENT vs. FLOW-THROUGH

An example of containment involves diversion of some part of a storm runoff to an area for treatment before discharging. The containment technique may target the initial pulse of runoff that generally is the most polluted, or it may seek to retain the entire storm discharge.

Flow-through methods include particle traps, settling tanks, marshes, and skimmers. These methods seek to cleanse the water in realtime. Flow-through methods are useful because the large volume of water can be immediately discharged with only a small volume of pollutant retained. The need for large storage capacities are minimized. The small volume of pollutant may then be treated in nonrealtime and released, or removed and disposed of elsewhere.

## TRUE REMEDIATION

The NPS control technology must consider pollution of air, surface runoff, groundwater, etc. For instance, spraying polluted water over a large ground area for biodegradation is only viable if the pollutant is in fact degraded, not volatilized or leached into the groundwater. Another example of pollution would be aeration of a water discharge to liberate the volatile contaminants. If the vapor is not treated, the contaminant has merely changed media—generally not a desirable approach to treating NPSP problems.

# IMPLICATIONS FOR MONITORING

## TEMPORAL/SPATIAL SCALES

To measure control effectiveness requires a comparison of pollution discharge before and after the control scheme on either a spatial or temporal scale. If the pollutant-containing medium is passed through a control scheme which filters pollutants, then measuring the effectiveness means showing a reduction in pollution as the medium passes through the filter. Transfer of pollutant from one medium to another may be adequate remediation. If not, the pollutant must be disposed of to effect remediation.

A temporal control scheme would be used to demonstrate effective remediation at a facility which formerly released pollution but no longer does so. Validation of effective mitigation requires a temporal analysis which spans the process change.

# WHAT TO MONITOR

## DEFINING THE POLLUTANTS

If the drainage basin is well defined, and the current and the historical activities are known, a good approximation of expected contaminants can be made. A diverse or poorly defined chemical history in the drainage basin requires a more expansive and expensive chemical scan to characterize the problem.

## SELECTING APPROPRIATE REMEDIATION TECHNIQUE

Having defined the NPSP problem, a remediation technique designed to mitigate the problem should be chosen. Application of the proper technique requires this understanding of the problem. The various control techniques are best suited to different pollutants, so proper technique selection requires knowledge of the pollutant content.

## MONITORING BASED ON IMPETUS FOR REMEDIATION

The impetus for remediation often dictates what should be monitored. The remediation likely is prompted by regulatory requirements. The Clean Water Act established two types of regulatory approaches that guide the nation's water pollution control effort: the technology-based and the water-quality-based approaches. The technology-based approach relies on point source guidelines which contain discharge limits. The water-quality-based approach relies on water-quality standards. Standards are based on determinations made by the states for uses of particular water bodies, and the criteria necessary to protect these uses. Thus, the legal language (discharge amount vs. ambient levels) will likely guide the monitoring program. The parameters specified in the regulations must be the ones monitored. If the remediation is not in response to regulations which dictate the remediation and monitoring technique, then monitoring by the guidelines in the paragraph below are appropriate.

## MONITORING RELEVANT POLLUTANTS

The expected pollutants, which the technique is designed to remediate, are the ones which should be monitored. As mentioned before, pollutants not remediated with the technique will still cause environmental impact. Thus, demonstrated effectiveness of the technique for the targeted pollutants cannot be extrapolated to state that the entire pollution problem is remediated.

## MONITORING PARAMETERS; BIOLOGICAL, CHEMICAL

Ultimately, the goal of NPSP reduction is biological habitat protection. Environmental regulations share this goal but usually strive for it via the language of chemistry, not biology. These regulations are built on the scientific link between chemical concentrations and biological effects.

Similarly, monitoring the effectiveness of an NPS control technique has two facets. Chemical data can document the change in concentration before and after application of the technique. To preserve the underlying intent of the control technique, biological habitat protection should be documented as well. Thus, biological monitoring should also occur in the receiving water.

Biological monitoring serves as a quality control check for a largely chemical monitoring program. Chemical analyses only quantify the chemicals for which you are looking. If pollutants are present for which the analyst is not looking, the chemical data alone may indicate a "safe" discharge. However, biota may be harmed from the unmeasured pollutant.

## INTERPRETING THE BIOASSAY

A bioassay measures biological response to a toxicant or effluent. The bioassay gives a specific set of information that is influenced by the pollutants, organisms used, and experimental setup. The toxicity of the pollutants is determined by the following factors:

1. Chemical properties (pH, solubility etc.)

2. Physical properties (size of particle, density, etc.)

3. Vehicle which carries the toxicant (e.g., a pesticide dissolved in water is much less toxic than if dissolved in oil)

4. Other contaminants

5. Dose (function of exposure concentration, uptake rate, and duration)

6. Route (e.g., ingested elemental mercury is almost nontoxic to humans, but inhaled vapor is highly toxic)

7. Time (acute, chronic, affects dose and rate of exposure)

8. Species of animal.

   a. Animals have different chemical and structural make-ups, and metabolic mechanisms. A physical or chemical site or metabolic step that is the target of a toxicant may be present or absent in different species.

   b. Most toxicants are not toxic in the form which they enter the body but are converted metabolically into a toxic substance. The different metabolism in the different animals may or may not produce the toxic substance.

9. Other stresses present—If the test organisms are stressed (e.g., nutritional deprivation, hormonal activity, caged test conditions), their vulnerability is generally increased.

10. Age—The differences in youthful and adult behaviors may alter the exposure rates of the test organism. A youthful metabolism is geared for growth and development and not for repair. Most metabolic processes are already slowed in the older organism. Further repression by a toxicant may lower the metabolic process to an unsafe or lethal level and slow repair mechanisms.

The utility of bioassays generally is in the extrapolation beyond experimental conditions. With all the variables associated with bioassay data, it is apparent that extrapolation of bioassay data to other conditions can be in error. Despite its limitations, a bioassay does give useful information. A bioassay gives an indication of the biological activity of a substance. The greater the variety of animals and test conditions used, the more general and valid a statement can be made about the toxicity of a substance.

The expense of bioassays varies greatly depending on duration, equipment needed, animals, etc. Since no single or series of bioassays can show the total toxicity, inexpensive informative tests are also needed.

Control technology effectiveness can be shown biologically or chemically. A biological indicator which registers a change in toxicity or a reduction in chemically measured toxicant from before to after the NPS control technology will document the effectiveness. Note that this cannot be done blindly. The toxicant which caused the effect may, in fact, have been detoxified, but many other factors, such as the following, may have occurred: (1) conversion to another toxicant not registered by the assay method or (2) for bioassays, other test conditions, which in combination with the substance produced the toxic response, may have changed. In this case, the substance may still be present but toxic effects won't appear.

## WHERE TO MONITOR

Appropriate sampling locations are highly application specific. The end-of-the-line sampling is appropriate for environmental impact assessment because it shows what is being released to the environment. In addition, sampling at some distance from the end-of-the-line clarifies what is happening to the pollutants as they interact with the environment. The distant samples also will show how the environment is responding to the pollutant release. Samples of unaffected background areas should be obtained for comparison with the effluent exposed area.

If the discharge has multiple sources and source-level reduction is desired, then sampling of each of the components of the total is necessary. This should indicate the origin of the chemicals with the greatest environmental harm.

## WHEN TO MONITOR

### TIME VARIANCE OF THE POLLUTION

Steady or nonsteady state output requires different monitoring. If variable, it may be episodic or predictably variable over a day, week, season, etc. This time variance partially dictates the number and temporal distribution of the sampling. Episodic fluctuations require the greatest number of samplings to characterize the discharge.

### CONTINUOUS OR DISCRETE SAMPLING

If pollutant release is periodic or easily predicted, discrete sampling is sufficient. Under these conditions, continuous data are of no advantage since no additional knowledge results, and data volume makes storage and processing more cumbersome. If, however, pollutant release is episodic or unpredictable, continuous sampling is needed. These are situations where continuous sensors are needed to characterize a discharge. Often, this situation requires a vastly different and more complicated apparatus for the parameters of interest. Included in the void of sensor technology are many of those needed for NPS runoff monitoring.

## CHANGES IN DRAINAGE BASIN

Activities or processes in the drainage basin may have cyclical or episodic changes which result in changes in the runoff. Monitoring would have to include sampling during each of these characteristic runoff intervals. The annual rain cycle variations cause different pollution concentrations and volumes which the sampling plan must quantify.

## CHANGES IN RECEIVING WATER

Target species and the biotic community in general undergo fluctuations which often affect vulnerability to pollution. Species often have more sensitive life stages when they need the greatest protection. Negative impact of the pollutants may only occur in conjunction with other factors (e.g., other pollutants, physical environmental conditions). Thus, the apparent toxicity of pollution may change with time.

The concept of higher and lower biological vulnerability intervals and exposure rates underlies one of the purposes for retention ponds. In addition to pollutant degradation and removal, which may occur during retention, the option for release during relatively safe intervals is provided.

This timing of storage and release must be cognizant of environmental storage. If the runoff pollutants have a short environmental storage (such as binding to sediment material) and rerelease during the biological vulnerable period, the timing of safe runoff discharge is complicated. Runoff discharge must allow ample time for environmental storage and rerelease to near completion before the interval of vulnerability.

The implications for monitoring are that a working knowledge of the biological community impacted by the pollutants in the runoff is needed. This will indicate when monitoring is important and, equally important, when monitoring is unnecessary because discharge is of little environmental importance.

# CONCLUSIONS

1. NPSP is a diverse problem because of many pollutants, many discharge regimes, and many receiving water bodies.

2. Control techniques target groups of compounds. No universal best technique exists.

3. Proper matching of the control technique to the NPSP problem is crucial to effect remediation.

4. No single or small set of measurement methods is adequate to document the effectiveness of NPSP control techniques. Insightful matching of documentation method to the control technique is necessary. Figure 1 summarizes this decision making process.

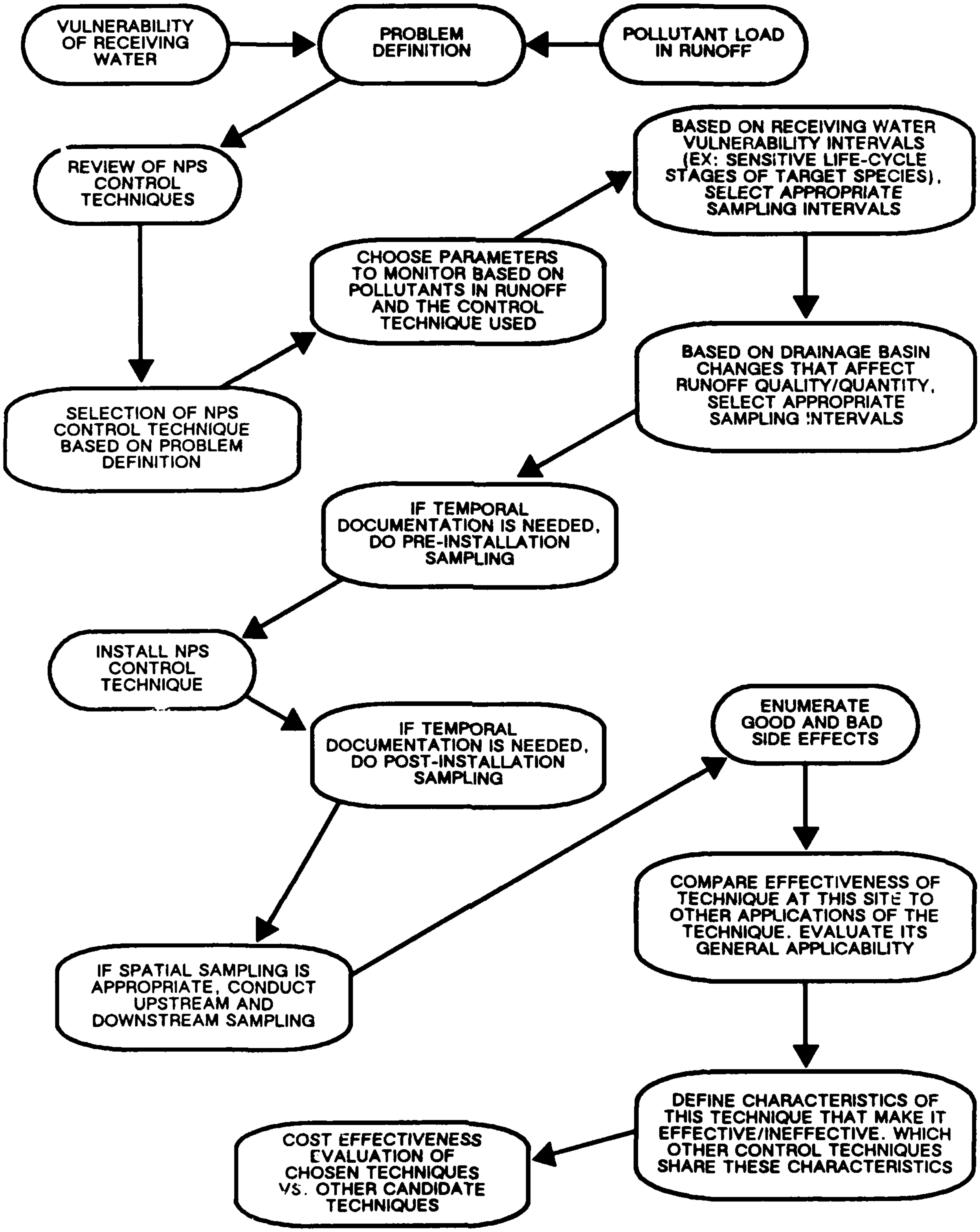


**Figure 1.** Control technique method selection and evaluation.

## RECOMMENDATIONS

1. Broaden knowledge of the discharge character of NPSP under different drainage basin conditions by chemical, physical, and biological assays of runoff.

2. Conduct test installations of control techniques and quantify their effectiveness for different pollutant types.

3. Obtain data sufficient to generate a three-way table with the following headings:

   a. Pollutant Type,

   b. Receiving Water Characteristics, and

   c. Control Technique Effectiveness. This knowledge will allow facility planners to choose the least expensive, most effective remediation technique.

4. Now, before NPSP becomes tightly regulated, is the time for the Navy to test control technologies. Once regulated, there will be little flexibility in remediation and monitoring methodology. The current interim period between problem awareness and tight regulation provides an opportunity to develop and document effective low-cost practical solutions that are particularly suited to the Navy.

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